26 November 2004
VE51295

Nunavut Water Board
P.O. Box 119
Gjoa Haven, Nunavut
X0E 1J0

Attention: NWB Licensing Administrator

Re: Amendment to Jericho Project Suggested Nitrite Discharge Criteria

Environment Canada has brought to AMEC's attention that the nitrite criteria were calculated incorrectly in that the CCME guideline was taken to be Nitrite nitrogen, rather than nitrate. This makes a difference in the allowable discharge calculated as nitrite nitrogen. Our other conclusions, however, remain unchanged, as outlined in the attached documents. We have attached:

- the amended page to SRK's Technical Memorandum O (NWB Water Licence application Appendix V);
- the amended pages in the appendix to the above memorandum;
- an e-mail from our aquatic toxicologist Mr. James Elphick explaining the effects of the correction.

Please do not hesitate to contact the undersigned if you have any questions or require further clarification.

Yours truly,

Bruce Ott, Ph.D.
Senior Environmental Scientist
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c: Ms. Anne Wilson, Environment Canada
Mr. Greg Missal, Tahera Diamond Corporation

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- Copper: A site specific receiving water quality objective of 0.004 mg/L has been proposed for the Jericho site (Attachment O1). This value has been proposed on the basis of chronic toxicity data from the U.S. Environmental Protection Agency (EPA), which indicates only one test with adverse effects at copper concentrations of less than 0.004 mg/L (the effect level in this test was at 0.0039 mg/L). Baseline copper concentrations in the Jericho River system are already at 0.002 mg/L. Therefore, the proposed water quality objective represents only a slight increase above current levels.

- Nitrite: A site specific receiving water quality objective that varies over a range of chloride concentrations has been proposed for the Jericho site, ranging from 0.03 mg/L nitrite (at a chloride concentration of 5 mg/L) to 0.25 mg/L nitrite (at chloride concentrations of >20 mg/L). At the mixing ratio of 10:1 used in the derivation of discharge water quality objectives (see Section 3), chloride is expected to be in the range of 48 mg/L, and the site specific objective would be 0.25 mg/L nitrite.

- TDS: The review of potential aquatic effects from TDS ("*Technical Memorandum N: Estimates of Receiving Water Quality for the Jericho Project*", SRK 2004b), indicated that there would be negligible effects at concentrations below 400 mg/L bulk TDS. The most stringent guidelines for TDS components are from British Columbia, at 150 mg/L for chloride and 100 mg/L for sulphate. These values are below the lowest effects levels identified in the literature. Effects levels for the cations (i.e. calcium, magnesium, potassium, and sodium) present in the PKCA discharge are generally below the lowest effects levels. Therefore, minimal dilution is required to ensure concentrations are below effects levels in the receiving environment.

The Aquatic Thresholds proposed for this project are summarized in Table 2.1. The table includes all of the parameters specified in recent water licences issued for Ekati, Diavik and Snap Lake, plus additional parameters raised as potential concerns at this site. However, consistent with these other applications, aquatic thresholds for TSS and phosphorus are not applicable. Therefore, as discussed in Section 4, the discharge criteria for these parameters are based on precedents set for other northern water licences that are also considered to be protective of the receiving environment.

5.0 NITRITE

5.1 Basis for the CCME Guideline for Nitrite

Salmonids are generally considered to be among the most sensitive species to nitrite (Lewis and Morris, 1986). Elevated nitrite concentrations cause methemoglobinemia resulting in a reduction of the oxygen carrying capacity of the blood (Brown and McLeay, 1975), in addition to exhibiting adverse effects on the liver (Jensen, 1996) and the retina (Hofer and Gatumu, 1994).

Russo et al. (1974) reported 96-hr LC50 values for toxicity of nitrite (as NO_2-N) to rainbow trout ranging from 0.19 to 0.39 mg/L. These authors also reported that the highest concentration tested that did not result in mortalities to rainbow trout in a 10-day exposure was 0.06 mg/L for 235 g fish and 0.14 mg/L for 2.3 g fish; 240-hr LC50 estimates were 0.39 and 0.20 mg/L in these tests, respectively.

Steelhead trout exhibited a small amount of tissue damage in the gills following a 6-month exposure to 0.06 mg/L NO_2-N, although no adverse effects were observed on survival or growth (Wedemeyer and Yasatuke, 1978).

Thurston et al. (1978) reported 96-hr LC50s (as NO_2-N) for cutthroat trout of 0.5 – 0.6 mg/L and 0.4 mg/L for a 36 day exposure, and concluded that cutthroat trout were generally similar to rainbow trout in their sensitivity to this parameter. In summarizing the available literature, these authors concluded that LC50 values fall in the range of 0.2 to 0.4 mg/L for rainbow trout and 0.4 to 0.6 mg/L NO_2-N for cutthroat trout.

The CCME guideline for nitrite is 0.06 mg/L (as NO_2) and is largely based on the data presented above for rainbow and cutthroat trout. This corresponds to a guideline of approximately 0.02 mg/L NO_2-N.

5.2 Relevance of the Guideline to the Receiving Environment at Jericho

The data upon which the CCME guideline was derived appear to be applicable to the receiving environment at Jericho because salmonids occur in the receiving environment. However, information on the mechanism of nitrite toxicity have been presented which are applicable to determining safe levels for this parameter to salmonids under the water quality conditions associated with this particular site and discharge.

Uptake of nitrite across the gill generally occurs through chloride channels, which are responsible for maintaining the chloride gradient across the gill in freshwater fish. In particular, these channels are designed to concentrate chloride inside the gill relative to the external environment. Because nitrite is able to enter the fish through these channels, under some circumstances, salmonids will also concentrate nitrite against its concentration gradient (Bath and Eddy, 1980), such that the internal concentration of this parameter can exceed the external concentrations.

Elevated external concentrations of chloride inhibit uptake and toxicity of nitrite, likely as a result of competition at the uptake sites. For example, Eddy et al. (1983) demonstrated that nitrite was almost harmless to Atlantic salmon except in waters with very low chloride concentration. Bartlett and Neumann (1998) also reported decreased toxicity of nitrite to brown trout alevins in water with 10 mg/L, relative to 3 mg/L chloride. Similarly, Russo et al. (1981) demonstrated that increasing chloride from approximately 1 to 10 mg/L resulted in a ten-fold reduction in the sensitivity of trout in a 96-hr exposure.

Wedemeyer and Yasatuke (1978) showed that acute nitrite toxicity to salmonids is ameliorated by the addition of calcium chloride and sodium chloride. Addition of 25 mg/L calcium chloride to the exposure water decreased the toxicity of nitrite by a factor of twelve (LC50 values were 0.6 and 7.3 mg/L NO_2-N in 2 and 19 mg/L chloride solutions). Addition of sodium chloride did not have as dramatic an effect, resulting in only a two-fold reduction in toxicity between concentrations of 1 and 18 mg/L chloride. The much lower degree of toxicity reduction associated with sodium chloride addition than with calcium chloride does not appear to agree with other literature, which demonstrate that chloride is the primary factor responsible for modulation of nitrite toxicity to salmonids (Lewis and Morris, 1986). The explanation for the inconsistency in these data is not known; regardless, all of the data demonstrate that the presence of chloride ameliorates the toxicity of nitrite to salmonids.

Acute toxicity data (LC50s) summarized above are presented in Figure 5 in relation to the chloride concentration in the water in which the tests were conducted. Only the maximum and minimum value are shown (connected by a line) for studies in which multiple data points were reported for the same chloride concentration. In general, toxicity is substantially reduced with increasing chloride concentration. As indicated above, the salmonid toxicity data resulting from sodium chloride additions conducted by Wedemeyer and Yasatuke (1978) do not appear to agree with the other data with regard to the degree of protection afforded by chloride; these data are shown as open round datapoints in Figure 5 to distinguish them from the remainder of the dataset. In a review of the effects of nitrite of toxicity to fishes, Lewis and Morris (1986) excluded these data as inconsistent; however, in taking a conservative approach to developing a proposed site-specific guideline, we have included those data, regardless.

Average discharge conditions at Jericho are predicted to contain approximately 490 mg/L of chloride. Thus, a twenty-fold dilution of the discharge will contain approximately 20 mg/L chloride. Tests conducted in water with 10 mg/L chloride, or higher, all exhibited LC50s exceeding 3 mg/L NO_2-N, except for the LC50 data of 0.8 – 1.5 mg/L NO_2-N for the NaCl spiked waters from Wedemeyer and Yasatuke (1978). Thus, the LC50 data for sodium chloride spiked water from Wedemeyer and Yasatuke (1978) reflect a highly conservative estimate of the LC50 to salmonids across this range of chloride concentrations, particularly considering that the chloride in the discharge is present with a mixture of counter-ions, in particular, magnesium, calcium and sodium, rather than sodium alone.

Applying a three-fold safety margin to the lowest value reported by Wedemeyer and Yasatuke (1978) results in a site-specific guideline value of 0.25 mg/L nitrite for chloride concentrations of 20 mg/L or higher. The CCME guideline (0.02 mg/L NO_2-N) appears appropriate for waters

with a chloride concentrations less than 1 mg/L. Extrapolating between these values results in a proposed guideline for nitrite for waters with chloride concentrations between 1 and 20 mg/L chloride given by the equation:

Proposed nitrite guideline (mg/L NO_2-N) = (0.0123 x [chloride (mg/L)]) + 0.0032

The proposed site-specific guidelines are shown in Figure 6 in relation to the most sensitive data from Figure 1. This figure shows that the proposed guideline is well below all reported LC50 values for chloride.

5.3 Summary

The CCME guideline for nitrite is based on toxicity to salmonids. Data in the literature demonstrate that uptake and toxicity of nitrite to salmonids is directly linked to chloride concentrations in the sample matrix; thus, it appears appropriate to alter the guideline in cases where chloride concentrations are elevated, as will occur at the Jericho mine. Proposed guideline values are shown in Figure 6 and summarized in Table 2.

A 10-, 20- and 50-fold dilution of the discharge would contain approximately 47, 24 mg/L and 10 mg/L chloride under average conditions, at which point the proposed guideline would be 0.25, 0.25 and 0.13 mg/L NO_2-N, respectively.

Table 1. Proposed site-specific water quality guideline for nitrite.

Chloride Concentration (mg/L)	Proposed Nitrite Guideline (mg/L NO_2-N)
≤ 1	0.02
2	0.03
5	0.06
10	0.13
15	0.19
≥ 20	0.25

Figure 1. LC50 data for nitrite presented on the basis of chloride concentration in the water used for the test. Open round datapoints are from Wedemeyer and Yasatuke (1978) and are conservative indicators of potential for effects at the corresponding chloride levels.

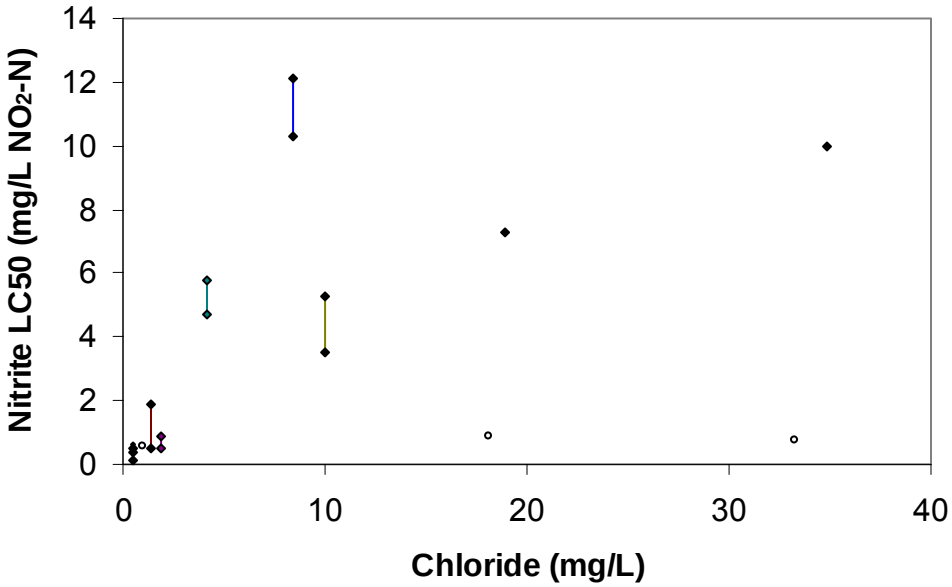
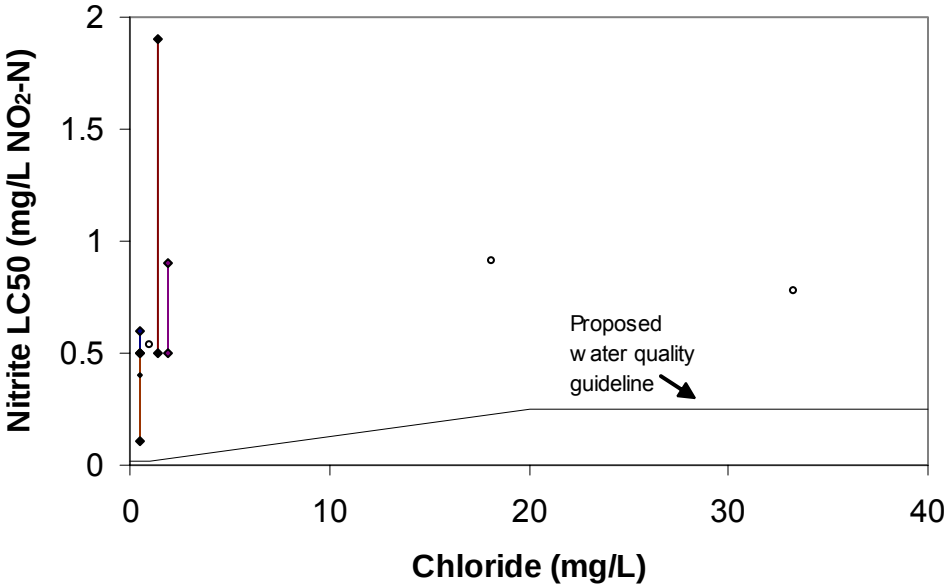


Figure 2. Proposed site-specific water quality guideline for nitrite compared with the most sensitive salmonid LC50 data from the literature.



E-Mail From James Elphick,
20 November 2004
Good afternoon Bruce,

Thanks for forwarding comments from Anne Wilson. She has correctly pointed out an error in the derivation we used. In particular, I had understood incorrectly that the CCME water quality criterion for nitrite (0.06 mg/L) was as NO2-N. In fact, it is as NO2, which is unusual, since convention is to report NO2 as N.

This does not have a profound effect on the numbers. The values we have proposed were based on a linear relationship between 0.06 mg/L NO2-N at 1 mg/L chloride, and 0.25 mg/L NO2-N at 20 mg/L chloride. In fact, since the guideline was published as NO2, then this relationship should have been between 0.0157 mg/L NO2-N at 1 mg/L chloride and 0.25 mg/L NO2-N at 20 mg/L chloride. Thus the numbers in Table 2 should be adjusted somewhat. I have provided what the numbers should be in the following Table. I have presented them both as NO2, and as NO2-N. Personally, I think it makes more sense to use NO2-N since this is the way analytical laboratories would typically report data on this parameter.

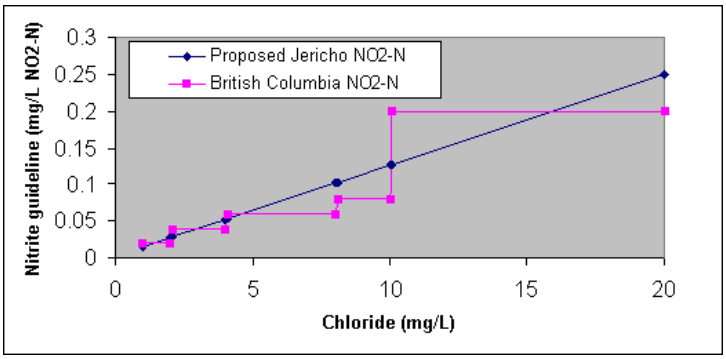
Proposed site-specific water quality guideline for nitrite.

Chloride concentration (mg/L)	Proposed nitrite mg/L NO2	Proposed nitrite mg/L NO2-N	Incorrect NO2-N numbers from report (for comparison)
≤ 1	0.06	0.02	0.06
2	0.11	0.03	0.07
5	0.25	0.06	0.10
10	0.48	0.13	0.15
15	0.72	0.19	0.20
≥ 20	0.96	0.25	0.25

Across the range of 1 to 20 mg/L chloride, the proposed guideline in mg/L NO2-N is calculated as follows:
Proposed nitrite guideline (mg/L NO_2-N) = (0.0123 x [chloride (mg/L)]) + 0.0032

Interestingly, since conducting this evaluation, I have had a look at the British Columbia water quality criterion for nitrite (30 day average). They took a similar approach to the one that we took with respect to chloride and generally have similar numbers across the range of chloride concentrations discussed; thus, there is some regulatory precedent for incorporating chloride into nitrite water quality guidelines.. For interests sake, I have included a figure below showing the BC criterion and our proposed criterion (with the corrections identified above) across the range of 0 to 20 mg/L chloride. As you can see, we have a very similar values (all values are mg/L NO2-N).

Comparison of proposed Jericho nitrite guideline and BC (30 day average) water quality criterion for nitrite.



It should be noted that the values driving our proposed guideline at elevated chloride concentrations are conservative. They are based on an approximate three-fold safety margin below two LC50s from work conducted by Wedemeyer and Yasutake (1978), in which LC50 values of 0.9 and 0.8 mg/L NO2-N were reported at chloride concentrations of 18 and 33 mg/L. These two LC50s appear to be outliers (substantially more sensitive) in relation to the remaining dataset at this level of chloride, including other LC50s from the same study of 7.3 mg/L NO2-N at 19 mg/L chloride, and higher nitrite LC50s at higher chloride levels.

Please let me know if the figure or table presented above is illegible as a result of transfer, and I will send this in a different format. Also, please feel free to call should you or Anne Wilson require any further clarification.

Regards,

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References

Wedemeyer, G.A. and Yasutake, W.T. 1978. Prevention and treatment of nitrite toxicity in juvenile steelhead trout (Salmo gairdneri). J. Fish. Res. Board Can. 35:822-827.